ISSN (print) 0093-4666 © 2012. Mycotaxon, Ltd. ISSN (online) 2154-8889

MYCOTAXON

http://dx.doi.org/10.5248/122.187

Volume 122, pp. 187–195 *October–December 2012*

Two species of *Agaricus* sect. *Xanthodermatei* from Thailand

Rui-Lin Zhao[1*], Dennis E. Desjardin[2], Philippe Callac[3], Luis A. Parra[4], Jacques Guinberteau[3], Kasem Soytong[5], Samantha Karunarathna[6], Ying Zhang[1] & Kevin D. Hyde [6, 7, 8]

[1]*Key Laboratory of Forest Disaster Warning and Control in Yunnan Province, College of Forestry, Southwest Forestry University, Kunming, Yunnan Province 650224, PR China*
[2]*Department of Biology, San Francisco State University, San Francisco, California, 94132, USA*
[3]*INRA, UR1264, Mycologie et Sécurité des Aliments, 33883 Villenave d'Ornon, France*
[4]*Avda. Padre Claret 7, 5º G, 09400 Aranda de Duero, Burgos, Spain*
[5]*Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Ladkrabang, Bangkok 10520, Thailand*
[6]*Institute of Excellence in Fungal Research, School of Science, Mae Fah Luang University, Chiang Rai, Thailand*
[7]*International Fungal Resource and Development Centre, The Research Institute of Resources Insects Chinese Academy of Forestry, Bailongsi, Kunming, Yunnan Province 650224, PR China.*
[8]*King Saud University, College of Science, Botany and Microbiology Department, Riyadh 1145, Saudi Arabia*
* Correspondence to: *zhaoruilin@gmail.com*

Abstract —*Agaricus murinocephalus* is described and illustrated as a new species. This taxon, presently known only from Thailand, is characterized by a context that generally does not discolor on exposure, the lack of a phenolic odor, a cap covered by very fine, appressed, dark grey squamules outside the grey disc on a whitish background, and a broken collar-like annulus. *Agaricus endoxanthus*, previously reported from South America, Europe, and Asia, is recorded for the first time in Thailand. Morphological and published molecular analyses place both taxa in *A*. sect. *Xanthodermatei* based on.

Key words —*Basidiomycota, Agaricaceae*, new species, taxonomy, tropics

Introduction

Agaricus is a genus that comprises many edible species but also includes a small number of species that are toxic if eaten. These toxic taxa do not generally cause death but may cause gastrointestinal upsets. Most toxic species are members of *A*. sect. *Xanthodermatei* (Parra 2008).

Agaricus sect. *Xanthodermatei* was established by Singer (1948) with the type species *A. xanthodermus* Genev. Recent molecular phylogenetic analyses of samples from Europe and North America showed the section to be monophyletic (Callac & Guinberteau 2005, Challen et al. 2003, Geml et al. 2004, Kerrigan et al. 2005). Inclusion of tropical species in molecular analysis by Zhao et al. (2011) also confirmed monophyly of the group. *Agaricus* sect. *Xanthodermatei* is characterized mainly by its chemical reactions as all section members have a negative Schäffer reaction and bright yellow positive KOH reaction (Parra 2008). Other important features shared by many taxa in sect. *Xanthodermatei* are a transient yellowing discoloration in the pileus surface and stipe base when bruised or cut, phenolic or iodine-like odors, and toxic compounds that can cause gastrointestinal disorders in humans. Surprisingly *A. biannulatus* Mua et al., a recently published new species in this section has neither yellow context discoloration nor a phenolic or iodine-like odor (Parra et al. 2011). Sect. *Arvenses* and sect. *Minores* (also with yellow staining species) can be distinguished from sect. *Xanthodermatei* by their more persistent color change, positive Schäffer reaction, anise seed or almond-like odors, and lack toxic compounds causing gastrointestinal upset when ingested (Parra 2008).

As part of our ongoing studies of macrofungi in northern Thailand (Van de Putte et al. 2010), including *Agaricus* (Zhao et al. 2011) and its relatives (Zhao et al. 2010), we describe here two *A.* sect. *Xanthodermatei* species from the region: one a newly proposed species and the other a first record for Thailand.

Materials & methods

Collections were made in forests and grassy areas in northern Thailand between 2004 and 2010. Specimens were photographed in situ and gathered and wrapped in aluminum foil or kept separately in a box in order to avoid mixing or crushing, and returned to the laboratory for treatment. Odor and color change upon bruising were recorded when collecting. Descriptions of other macrocharacters, chemical tests, and further photography of fresh samples were carried out as soon as possible after return from the field, generally following Largent (1986). Color terminology follows Kornerup & Wanscher (1978). Specimens were dried overnight in a food drier, sealed in plastic bags, and deposited in the BIOTEC Bangkok Herbarium (BBH), with duplicates in the H.D. Thiers Herbarium at San Francisco State University (SFSU). Herbarium acronyms follow Thiers (http://sweetgum.nybg.org/ih continuously updated).

Micromorphological features were documented from examination of dried specimens according to Largent (1986). Particular attention was given to the anatomy of the pileipellis, stipitipellis and partial veil, and features of the hymenophoral trama, basidiospores, basidia and cystidia. Measurements of anatomical features (spores, basidia and cheilocystidia) are presented based on at least 20 measurements, and include x, the mean of length by width ± SD, Q, the quotient of basidiospore length and width, and Qm, the mean of Q-values ± SD. The phylogenetic relationships of the two species included herein are published in Zhao et al. (2011).

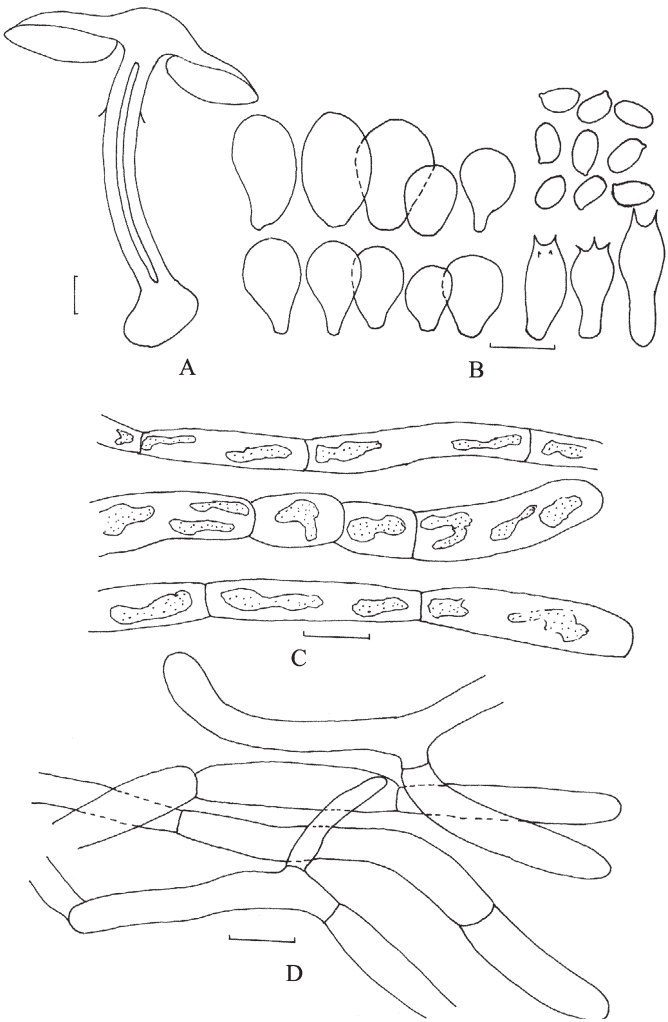

Plate 1. *Agaricus murinocephalus* (Holotype BBH 19560): A. Longitudinal section of basidiocarp; B. Basidiospores, basidia and cheilocystidia; C. Pileipellis hyphae; D. Annulus hyphae. Scale bars: A = 10 mm; B–D = 10 µm.

Taxonomy

Agaricus murinocephalus R.L. Zhao, Desjardin & K.D. Hyde, **sp. nov.** Pl. 1, 3a–e

MycoBank MB564460

Differs from other species of *Agaricus* sect. *Xanthodermatei* by its lack of (or very slight) yellow context discoloration on exposure, lack of phenolic or iodine-like odor, pileus disc with very fine grey squamules on a white background, and broken collar-like annulus.

Type: Thailand. Chiang Mai Prov., Mae Taeng, Ban Mae Sae village, on Hwy 1095 near 50 km marker, 19°14.599′N 98°39.456′E, altitude 962 m, 10 June 2006, coll. Todd Osmundson ZRL3044 (**Holotype**, BBH 19560; **isotype** SFSU; GenBank, JF691555).

Etymology: from *murinus* = mouse-grey, and *cephalus* = headed; referring to the grey-colored pileus.

Pileus 30 mm diam. when young, then expanding to 50–55 mm diam., convex with distinct broad umbo; margin deflexed, splitting with age, never uplifted; surface dry, covered with fibrils or very finely squamulose; disc generally greyish brown (5F5) to black or sometimes with greenish tones; ornamentation disrupted towards the whitish margin and appearing minutely pulverulent on a whitish background. Context 3 mm thick at disc, white. Lamellae free, crowded, with 4 series of lamellulae, 5–6 mm broad, ventricose, at first white, then light orange grey (6B2), later greyish brown (8D3), finally dull brown to dark brown. Stipe 40–70 × 4–5 (apex) × 5–10 (base) mm, cylindrical to subclavate above a bulbous base, hollow; surface smooth, silky, white. Annulus 2 mm broad, collar-like, broken, ephemeral, white. Odor pleasant. Surfaces of stipe and pileus staining reddish-brown on touching; context lacking color change or very slightly discoloring yellow at the base of stipe on cutting.

Macrochemical reactions KOH reaction bright yellow; Schäffer reaction negative.

Basidiospores 5.5–7 × 3–4 µm, [x = 6 ± 0.4 × 3.5 ± 0.3 µm, Q = 1.4–2.0, Q_m = 1.75 ± 0.35, n = 20], elongate-ellipsoid, without germ pore, smooth, brown. Basidia 12–19 × 6–8 µm, hyaline, smooth, 4-spored. Cheilocystidia scattered, 9–24 × 8–13 µm, pyriform to broadly clavate, hyaline, smooth. Pleurocystidia absent. Pileipellis a cutis formed from hyphae 5–10 µm diam., some constricted at septa, cylindrical, walls hyaline, containing brown vacuolar pigment. Annulus composed of hyphae of 4–7 µm diam. that are smooth, hyaline and branched.

Habit solitary or scattered in small groups in open areas of forest.

Additional material examined: **THAILAND**, **Chiang Rai Prov.**, Mae Sai, Doi Tung, 3 August 2006, coll.: Rui-lin Zhao ZRL3092 (BBH 19608, SFSU).

Agaricus endoxanthus Berk. & Broome, J. Linn. Soc. Bot. 11: 548. 1871. Pl. 2, 3f–h

Pileus 65 mm diam., convex to plano-convex; disc with a broad, flattened or slightly depressed umbo; pileus margin exceeding the lamellae as a white edge; surface dry, covered by brownish-grey (8E2) to grey (8E5) fibrils, radially fissured exposing the underlying white context that turns pink in wet conditions; at disc fibrils darker and aggregated into small, scattered fibrillose squamules. Context firm, white. Lamellae free, crowded, with 10 or more series of lamellulae, up to 4 mm broad, straight or ventricose, greyish red to dull red (8C3) when young, brown to dark brown (8F4) with age; edges paler than the sides. Stipe 60 × 4–12 mm, cylindrical below, with a slightly tapered

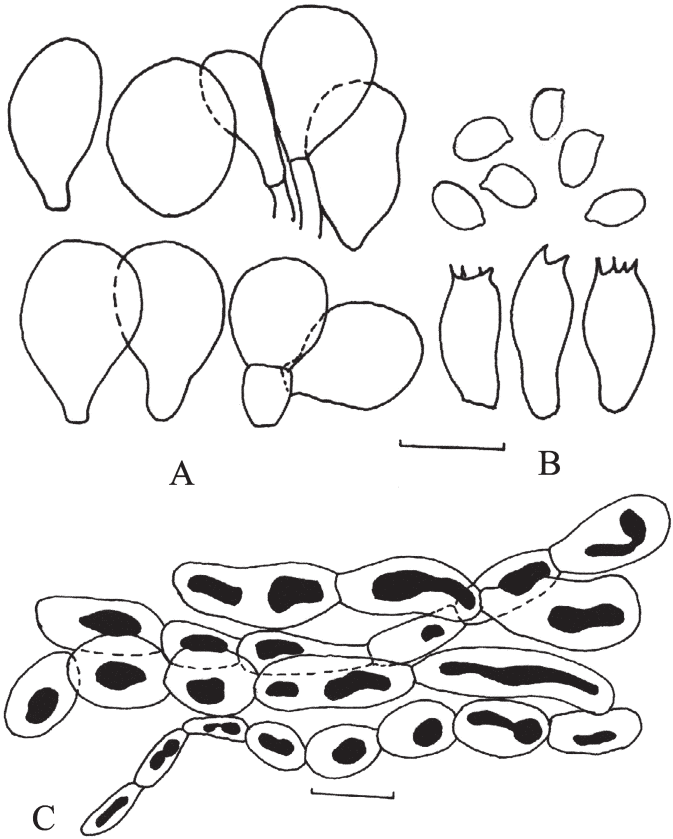

Plate 2. *Agaricus endoxanthus* (BBH 19611): A. Cheilocystidia; B. Basidiospores and basidia; C. Pileipellis hyphae. Scale bars: A–B = 10 µm; C = 25 µm.

apex: base slightly swallowed with white rhizomorphs, hollow; surface both above and below the annulus glabrous, brownish grey (8E2). Annulus superior, persistent, pendent, single, up to 11 mm broad; lower surface slightly floccose; edge entire, white, and sometimes with brown granules. Odor indistinct, not phenolic or almond-like. Base of stipe and centre of disc strongly staining yellow on cutting, without color change on touching.

Macrochemical reactions KOH reaction yellow; Schäffer reaction negative.

Spores 5–6 × 3–4 µm [x = 5.4 ± 0.6 × 3.5 ± 0.5 µm, Q = 1.25–2, Q_m = 1.55 ± 0.45, n = 20], ellipsoid with attenuate apex in most cases, without germ pore, smooth, brown. Basidia 12–17 × 5–7 µm, clavate, 4-spored. Cheilocystidia (9–)11–17 × 8–12 µm, rarely seen in old specimens, mostly pyriform, some turbinate

or subsphaerical, hyaline, smooth. Pleurocystidia absent. Pileipellis a cutis, composed of cells variable in size and shape, many 25–44 × 17–25 µm, others 17–25 × 5–7.5 µm, distinctly constricted at the septa, with dark brown vacuolar pigments. Annulus composed of hyphae of 5–7.5 µm diam., which are hyaline, smooth and curved. Stipitipellis with hyphae similar to those of the pileipellis, but slightly smaller.

Habit solitary in soil, in open areas of forest.

Material examined: **THAILAND**, **Chiang Mai Prov.**, Mae Taeng Dist., Ban Pha Deng Village, 19°17.123′N 98°44.009′E, elev. 900 m., 13 August 2006, coll.: Rui-lin Zhao ZRL3095 (BBH 19611, SFSU; see also Zhao et al. 2011).

Discussion

Although some morphological characters of *A. murinocephalus,* such as the slightly reddish-brown discoloration on bruising of the pileus and the lack of typical phenolic odor are not typical for *A.* sect. *Xanthodermatei*, the molecular phylogenetic position (Zhao et al. 2011), negative Schäffer reaction, positive KOH reaction, and pileipellis hyphae with vacuolar pigments support this new species in this section. Furthermore, the previous molecular work separates this new species from *A. endoxanthus*, *A. microvolvatulus* Heinem., *A. xanthodermulus* Callac & Guinb., *A. xanthodermus*, and *A. xanthosarcus* Heinem. & Gooss.-Font. Specimen NTF61 (see sp. 39 in the Zhao et al. 2011 phylotree) represents another possible species sister to *A. murinocephalus* that our molecular analyses show as a different new species. A complete morphological and molecular characterization of specimen NTF61 will be presented in another paper.

The context in *A. murinocephalus* either does not stain yellow or discolors only slightly on exposure. Most sect. *Xanthodermatei* species stain distinctly yellow after being cut, especially at the stipe base of the stipe, e.g. *A. bulbillosus* Heinem. & Gooss.-Font., *A. endoxanthus*, *A. iodosmus* Heinem., *A. moelleri* Wasser, *A. menieri* Bon, *A. pseudopratensis* (Bohus) Wasser, *A. xanthodermus*, *A. xanthosarcus* (Cappelli 1984, Heinemann 1956a, 1978; Kerrigan 1986, Nauta 2001). In some species, such as *A. phaeolepidotus* (F.H. Møller) F.H. Møller, *A. californicus* Peck, or *A. hondensis* Murrill, a weak yellow or rubescent discoloration occurs on cutting, however all taxa have a phenolic odor and lack a dark greyish pileus (Cappelli 1984, Kerrigan 1986, Nauta 2001) that characterize *A. murinocephalus*. *Agaricus biannulatus*, a recently published species (Parra et al. 2011) in this section also lacks a yellow context discoloration and phenolic or iodine-like odor, but differs from *A. murinocephalus* in a two-layered annulus consisting of two distinct separate limbs. *Agaricus volvatulus* Heinem. & Gooss.-Font. and *A. placomyces* Peck are morphologically similar to our new species in that both have blackish pilei and a bulbous stipe. *Agaricus volvatulus*, however, has a distinct phenolic odor and its pileus is darkly pigmented overall,

Plate 3. ***Agaricus murinocephalus***: A–C. Holotype BBH 19560; D–E. BBH 19608. ***Agaricus endoxanthus*** (BBH 19611): F. Basidiomata; G. Cheilocystidia; H. Pileipellis hyphae.

while *A. placomyces* has an elastic annulus that may remain attached to the pileus margin even after pileus expansion (Heinemann 1978, 1980; Kerrigan et al. 2005).

Agaricus endoxanthus is another species with dark appressed squamules on the pileus, a large membranous-floccose annulus, small spores and cheilocystidia, and vacuolar pigments in the pileipellis hyphae (Pegler 1977, 1986; Heinemann 1980). An ITS1+2 sequence of material from Thailand (sample ZRL3095, GenBank JF691554; Zhao et al. 2011) is nearly identical to that of *A. endoxanthus* (GenBank DQ182511) reported in Kerrigan et al. (2005). The fact that only two heteromorphisms separate the two sequences helped us select the appropriate epithet for the Thai material.

Agaricus endoxanthus is similar to *A. pseudoniger* Heinem. & Gooss.-Font. from Congo and *Agaricus rotalis* K.R. Peterson et al. from Hawaii (Peterson et al. 2000). *Agaricus pseudoniger* differs in having a brownish-black pileus and larger cheilocystidia (18–30 × 9.5–18.5 µm; Heinemann 1980, 1956b). *Agaricus rotalis* is morphologically nearly indistinguishable from *A. endoxanthus* (cf. comparison in Kerrigan et al. 2005), but they differ by three heteromorphisms in their ITS1+2 sequences.

Acknowledgments

We thank the National Natural Science Foundation of China (Project ID: 31000013 to Ruilin Zhao), Key Laboratory of Forest Disaster Warning and Control in Yunnan Province (Project ID: ZK09A107), the Bio-Asie project "Inventory and taxonomy of *Agaricus* species in Thailand, Laos, Malaysia and Yunnan (China); domestication and evaluation of species of nutritional or medicinal interest", and BRN grant (BRN049/2553) is acknowledged for support to study the taxonomy of potentially edible mushrooms in Thailand. We thank the USA National Science Foundation (PEET-grant DEB-0118776 to Desjardin) for partial support of Zhao and Desjardin. The Global Research Network for Fungal Biology and King Saud University are also thanked for support. Drs. Annemieke Verbeken, Xianghua Wang, and Zai-Wei Ge are thanked for helping us in preparing the final submission.

Literature cited

Callac P, Guinberteau J. 2005. Morphological and molecular characterization of two novel species of *Agaricus* section *Xanthodermatei*. Mycologia 97: 416–424. http://dx.doi.org/10.3852/mycologia.97.2.416

Cappelli A. 1984. *Agaricus* L.: Fr. (*Psalliota* Fr.). Libreria editrice Biella Giovanna, Saronno.

Challen MP, Kerrigan RW, Callac P. 2003. A phylogenetic reconstruction and emendation of *Agaricus* section *Duploannulatae*. Mycologia 95(1): 61–73. http://dx.doi.org/10.2307/3761962

Geml J, Geiser DM, Royse DJ. 2004. Molecular evolution of *Agaricus* species based on ITS and LSU rDNA sequences. Mycol. Prog. 3(2): 157–176. http://dx.doi.org/10.1007/s11557-006-0086-8

Heinemann P. 1956a. Champignons récoltés au Congo belge par Mme M. Goossens-Fontana, II. *Agaricus* Fr. s.s. Bull Jard Bot Brux 26: 1–127.

Heinemann P. 1956b. Sur divers facteurs agissant sur la formation des primordiums de *Agaricus edulis* en culture pure, VIlle Congrès de Bot., C R des séances et rapports et rapports et comm. déposées lors du Congrès. dans les sect. 18, 19 et 20: 48–50.

Heinemann P. 1978. Essai d'une clé de determination des genres *Agaricus* et *Micropsalliota*. Sydowia 30: 6–37.

Heinemann P. 1980. Les genres *Agaricus* et *Micropsalliota* en Malaisie et en Indonésie. Bull Jard Bot Nat Belg 50: 3–68.

Kerrigan RW. 1986. *Agaricales* of California. Vol. 6. *Agaricaceae*. Mad River Press, Eureka. California.

Kerrigan RW, Callac P, Guinberteau J, Challen MP, Parra LA. 2005. *Agaricus* section *Xanthodermatei:* a phylogenetic reconstruction with commentary on taxa. Mycologia 97: 1292–1315. http://dx.doi.org/10.3852/mycologia.97.6.1292

Kornerup A, Wanscher JH. 1978. Methuen handbook of color. Third Edition. Eyre Methuen, London.

Largent DL. 1986. How to identify mushrooms to genus, vols 1–5. Mad River Press, Eureka, California.

Nauta MM. 2001. *Agaricus* L. and *Allopsalliota* Naunta et Bas. 23–62, in: ME Noordeloos et al. (eds). Flora Agaricina Neerlandica, Vol. 5, Family *Agaricaceae*. Lisse, A.A. Balkema Publishers.

Parra LA. 2008. *Agaricus* L. *Allopsalliota* Nauta & Bas, Edizioni Candusso, Alassio.

Parra LA, Mua A, Cappelli A, Callac P. 2011. *Agaricus biannulatus* sp. nov., a new species of the section *Xanthodermatei* collected in Sardinia and Sicily. Micol. Veget. Medit. 26 (1): 3–20.

Pegler DN. 1977. A preliminary agaric flora of east Africa. Kew Bull 6: 1–615.

Pegler DN. 1986. Agaric flora of Sri Lanka. Kew Bull 12: 1–519.

Peterson KR, Desjardin DE, Hemmes DE. 2000. *Agaricales* of the Hawaiian Islands.6. *Agaricaceae* I. *Agariceae*: *Agaricus* and *Melanophyllum*. Sydowia 52(2): 204–257.

Singer R. 1948. Diagnoses Fungorum Novorum Agaricalium. Sydowia 2: 26–42.

Van de Putte K, Nuytinck J, Stubbe D, Le HT, Verbeken A. 2010. *Lactarius* volemus sensu lato (Russulales) from northern Thailand: morphological and phylogenetic species concepts explored, Fungal Divers. 45: 99–130. http://dx.doi.org/10.1007/s13225-010-0070-0

Zhao RL, Desjardin DE, Soytong K, Perry BA, Hyde KD. 2010. A monograph of *Micropsalliota* in Northern Thailand based on morphological and molecular data. Fungal Divers. 45: 33–79. http://dx.doi.org/10.1007/s13225-010-0050-4

Zhao RL, Karunarathna S, Raspé O, Parra LA, Guinberteau J, Moinard M, Kesel AD, Barroso G, Courtecuisse R, Hyde KD, Guelly AK, Desjardin DE, Callac P. 2011. Major clades in tropical Agaricus. Fungal Divers. 51: 279–296. http://dx.doi.org/10.1007/s13225-011-01360-7